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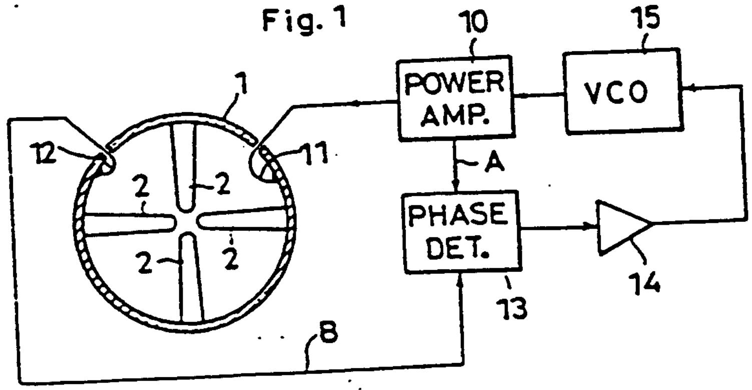
(54) Radio frequency linear accelerator control system.

(57) To control the power supplied to a resonant cavity of the accelerator to be always at the resonance frequency, the system consists of a signal pick-up coil (12) inserted in the resonant cavity (1,2), a voltage-control oscillator assembly (10,15), a phase detector (13) for detecting a phase difference between a signal picked up from the cavity (1,2) by the signal pick-up coil (12) and an output from the voltage-controlled oscillator assembly (10,15). An output from the phase detector (13) controls the voltage-controlled oscillator assembly (10,15) so as to make it oscillate at a frequency equal to a resonance frequency of the resonant cavity (10,15).

Fig. 1



RADIO FREQUENCY LINEAR ACCELERATOR CONTROL SYSTEM

Background of the Invention

The present invention relates to a radio frequency linear accelerator control system, and more particularly to a system for controlling a resonant cavity type radio frequency linear accelerator so as to be power-supplied always at a frequency tuned precisely with the characteristic resonance frequency of the cavity constituting the accelerator.

It is an essential requirement for a resonant cavity type radio frequency linear accelerator that the frequency of the power supplied to the accelerator should coincide with the characteristic resonance frequency of the cavity constituting the accelerator, because a slight discrepancy between the two frequencies causes a severe decrease in the efficiency of the accelerator owing to a high Q-value feature of the resonant cavity. Meanwhile, though the characteristic frequency of a cavity depends sensitively on the cavity dimensions, they vary owing to an inevitable thermal expansion (or contracton) occurring on the cavity during operation.

According to a conventional resonant cavity type radio frequency linear accelerator, to compensate a cavity resonance frequency change caused by thermal expansion, the cavity, which constitutes the accelerator, is generally provided therein with an externally motor-driven inductive tuner. A radio frequency signal picked up by a small pick-up loop inserted in the cavity has its phase compared at a phase detector with that of the radio frequency power being supplied to the cavity. If the resonance frequency characteristic of the cavity (including the inductive tuner) deviates from the frequency of the power being supplied to the cavity, the phase detector outputs a positive or negative signal reflecting the magnitude and direction of the resonance frequency deviation of the cavity. The output from the phase detector operates the motor driving the above inductive tuner so that the tuner makes the resultant resonance frequency of the cavity coincide with the frequecy of the power supplied to the cavity. In this manner the resonance frequency of the cavity can be kept at the same frequency as that of the radio frequency power being supplied to the cavity.

However, such a conventional cavity type radio frequency linear accelerator has a disadvantage that, because the resonace frequency compensation is achieved by a mechanical operation of the inductive tuner, it takes a somewhat long time for the tuner to respond to the resonance frequency deviation. This is unfavorable especially when the deviation is large and abrupt. In addition the inductive tuner must be provided with some slidable electrical contact means for making the tuner continue keeping a good and stable electric contact with the cavity drum during and after being operated. This not only makes the constitution complex, but also increases the manufacturing cost of the apparatus. Further, for a high power accelerator which is expected to have its temperature raised to a very high level resulting in a large thermal expansion of the cavity, one inductive tuner can not cover a desired extent of compensating the resonace frequency deviation of the cavity. In such a case it is necessary to provide a plurality of inductive tuners or a more powerful cooling means to the cavity. Further, in some cases, the inductive tuners themselves must be provided with cooling means. These also make the apparatus more complex and further expensive.

Objects and Summary of the Invention

It is an object of this invention to provide an improved resonant cavity type radio frequency linear accelerator control system form which are removed such disadvantages as mentioned above.

Another object of the present invention is to constitute such an improved accelerator control system only with an electric or electronic control means without using any moving or movable mechanical element.

To achieve the above objects, the radio frequency power source to supply power to the resonant cavity constituting an accelerator consists of a voltage-controlled oscillator and a power amplifier; while the resonat cavity, though provided with a signal pick-up loop, has no mechanically movable element such as an inductive tuner. The phase of a signal picked up by the pick-up loop of the cavity is compared at a phase detector, as similarly as in the case of the conventional control system, with the phase of the radio frequency power being supplied to the cavity, but the control voltage outputted from the phase detector is supplied, in the present invention, to the above voltage-controlled oscillator to control the frequency of the oscillator so as to coincide with the cavity resonace frequency which varies owing to the thermal expansion (or contraction) of the cavity.

According to the present invention, because the control system does not include any mechanical element such as an inductive tuner, the disadvantages previously mentioned in respect of a

conventional resonanct cavity type radio frequency linear accelerator are completely removed, and the response to a resonance frequency deviation has no time lag in substance.

Because the control system according to the present invention controls the frequency of the radio frequency power source so as to coincide with the resonance frequency of the cavity constituting an accelerator, the acceleration energy varies a little. However, it is to be noticed especially that there is no problem in applying the present control system to an accelerator as an ion implantor for use in a semiconductor device manufacturing process, that as a particle bombarder for use in surface improvement of materials and the accelerators having similar purposes, because the cavity resonance frequency change due to thermal expansion is generally around 0.5% at largest.

Brief Description of the Drawings

The present invention may be better understood by referring to the following description when taken in conjunction with the accompanying drawings, in which like reference signs and numerals refer to like constituents in all the figures, and in which:

Fig. 1 shows a blockdiagrammatical constitution of an embodiment of the present invention;

Fig. 2 shows a blockdiagrammatical constitution of a conventional accelerator control system; and

Figs. 3(A) and 3(B) shows two kinds of inductive tuner usable in the conventional accelerator control system shown in Fig. 2.

Detailed Description of the Invention

In advance of the detailed description of the present invention, the previously mentioned conventional accelerator control system is reviewed somewhat in detal in referece to Fig. 2, which shows the (conventional) control system applied to a known radio frequency quadrupole linear accelerator.

In Fig. 2 the radio frequency quadrupole linear accelerator to be controlled is shown as its schematical cross-sectional view taken orthogonally to the particle acceleration axis. The accelerator fundamentally consists of a cavity drum 1 and four vanes 2 provided therein, all forming a radio frequency resonant cavity. In each of four quadrant spaces partitioned by the vanes 2 in the cavity drum 1 is provided at least one externally motor-driven inductive tuner 30. In Fig. 2 are shown only two such inductive tuners 30 in two quadrant spaces. The cavity is further provided with a power input loop coupler 11 and a signal pick-up loop coupler 12. The cavity is power-supplied through the input loop coupler 11 from a radio frequency power amplifier 10 excited by a quartz-controlled oscillator 40. The signal pick-up loop coupler 12 takes out a small amount of power from the cavity and transmits its radio frequency voltage to a phase detector 13 through a route B. To the phase detector 13 is inputted another radio frequency voltage made to branch from the radio frequency power amplifier 10 through a route A. If the resonce frequency of the cavity (consisting of the cavity drum 1 and the vanes 2) deviates from the frequency of the power being supplied to the cavity, the phase detector 13 outputs a positive or negative voltage reflecting the magnitude and direction of the resonance frequency deviation of the cavity. The output from the phase detector 13 is amplified by a control voltage amplifier 14, and then fed to the motors 31of the two motor-driven inductive tuners 30 in order to operated them so as to make the cavity resonance frequency return to the frequency of the power being supplied to the cavity.

In Figs. 3(A) and 3(B) are schematically shown two typical examples of the motor-driven inductive tuners 30 used in the cavity shown in Fig. 2. The tuner shown in Fig. 3(A) is of a cylinder type, and a cylindrical tuner 32 is driven by a motor 31 so as to be inserted into or pulled out from the cavity. The tuner shown in Fig. 3(B) is of a loop type. According to this type a motor 31 rotates a short-circuited loop 33 by a suitable angle in reponse to a cavity resonance frequency deviation. Anyway, any one of these motor-driven mechanical tuners makes the cavity constitution complex. In Fig. 3(A), electrical contact means to be provided between the cylindrical tuner 32 and the cavity drum 1 is omitted for the simplification of the drawing.

In the following an embodiment of the present invention is described on reference to Fig. 1, which shows that a control system according to the invention is applied to a radio frequency quadrupole linear accelerator similar to that shown in Fig. 2 except for not being provided with any mechanical means such as motor-driven inductive tuners. According to the present invention, the quartz-controlled oscillator 40 in Fig. 2 is replaced by a well-known voltage-controlled oscillator 15, while the output from the phase detector 13 is fed to the oscillator 15 through a control voltage amplifier 14a in order to control the frequency of the oscillator 15

so as to be tuned to the cavity resonance frequency which varies owing to a thermal expansion (or contraction) of the cavity.

Claims

1. A control system for controlling a radio frequency resonant cavity type linear accerelator so as to be power-supplied at a frequency tuned at a characteristic resonance frequency of a cavity (1, 2) constituting said accelerator, characterized by a voltage-controlled radio frequency power source assembly (10, 15) for supplying a radio frequency power to said cavity (1, 2), a phase detector (13) for comparing the phase of a signal picked up from said cavity (1, 2) with the phase of a signal made to branch from said voltage-controlled radio frequency power source assembly (10, 15), and means (14) for supplying an output of said phase detector (13) to said radio frequency power source assembly (10, 15).

Fig. 1

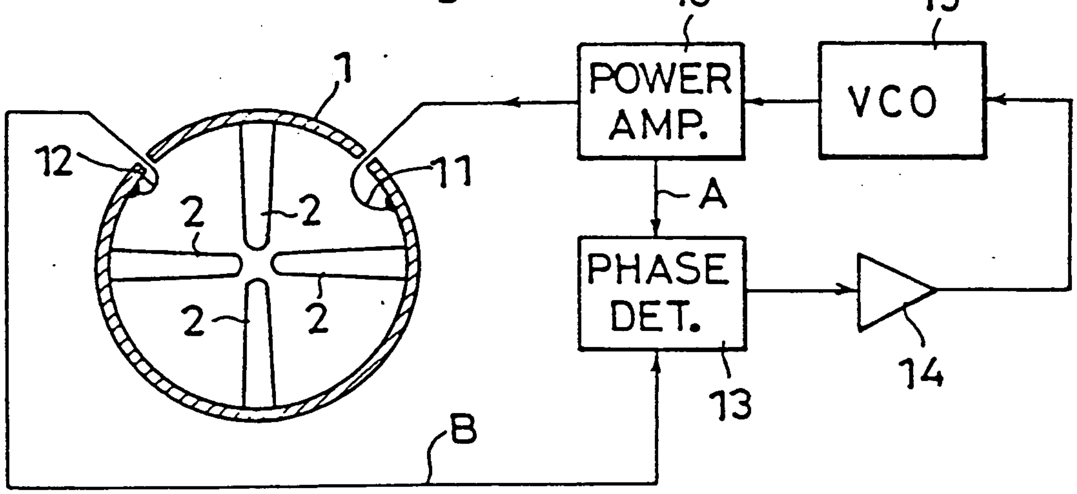


Fig. 2

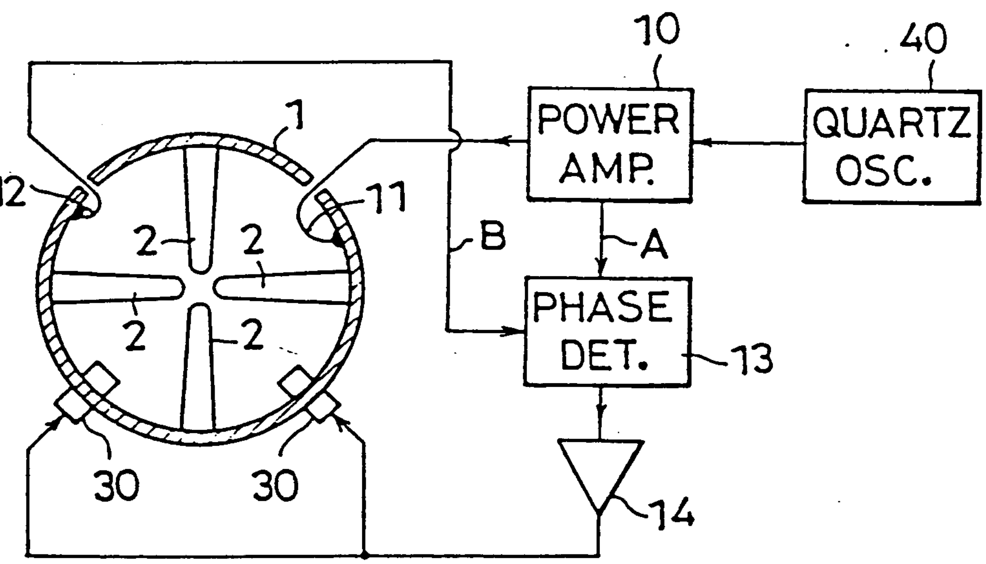


Fig. 3(A)

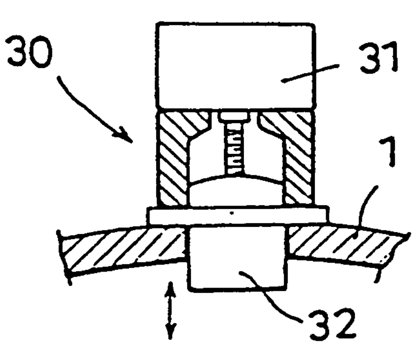


Fig. 3(B)

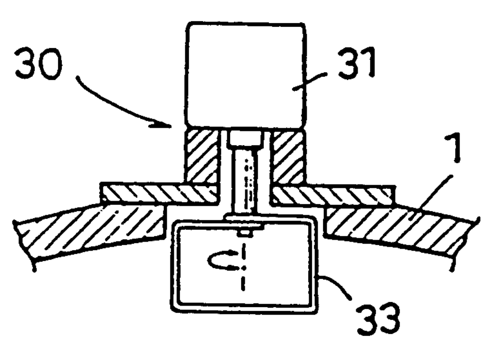


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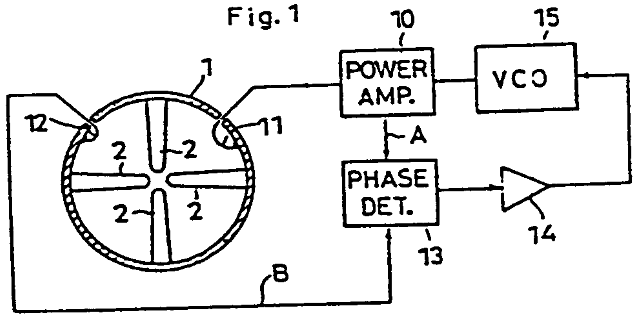
Fig. 1



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EUROPEAN SEARCH REPORT

Application Number

EP 89 30 5413

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	IEEE TRANSACTIONS ON NUCLEAR SCIENCE, vol. NS-30, no. 2, April 1983, pages 1446-1448, IEEE, New York, US; D. HOWARD et al.: "Vane coupling rings: A simple technique for stabilizing a four-vane radiofrequency quadrupole structure" * Page 1447, left-hand column: "Frequency tuning apparatus" *	1	H 05 H 7/02 H 05 H 9/00
Y	EP-A-0 163 745 (HITACHI) * Page 6, line 8 - page 7, line 7 *	1	
X	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH, vol. 224, no. 1/2, July 1984, pages 5-16, Elsevier Science Publishers B.V., Amsterdam, NL; T. GRUNDEY et al.: "Construction and first operation of a pilot CW superconducting electron accelerator" * Figure 9 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
X	FR-A-2 334 266 (CGR-MeV) * Figure 3; page 1, lines 26-28; page 4, lines 18-19; claim 1 *	1	H 05 H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	01-11-1989	FRITZ S.C.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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